Sulfuric acid and polymerized sulfur in the icy crust of Europa

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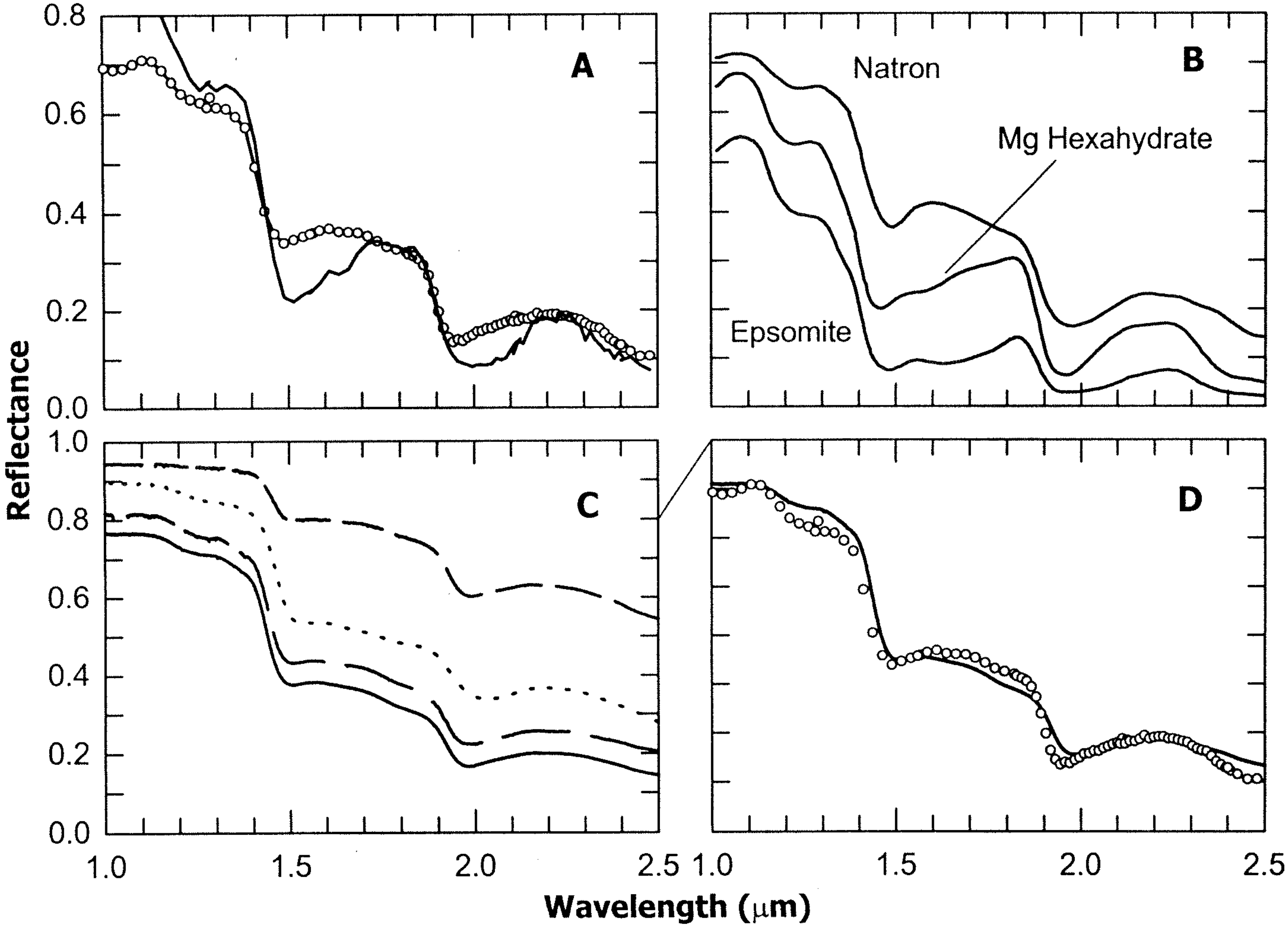
Comparisons of Galileo near infrared spectra with laboratory spectra indicate that hydrated sulfuric acid is present on Europa's surface and is a major component [1]. The spatial correlation of sulfuric acid with Europa's visually dark material, and the spectral similarity of this dark material with photolyzed and radiolyzed sulfur compounds, suggest that Europa's dark material is radiolytically altered sulfur polymers [1]. Sulfuric acid, polymerized sulfur, and sulfur dioxide [2] are chemical reservoirs through which sulfur is being continuously cycled by radiolysis, with most of the sulfur existing in the acid form due to the relative stability of sulfuric acid octahydrate and hemihexahydrate under irradiation. A long-term net imbalance in the production and oxidation of polymerized sulfur may lead to the observed brightening of Europa's dark linear features with time.

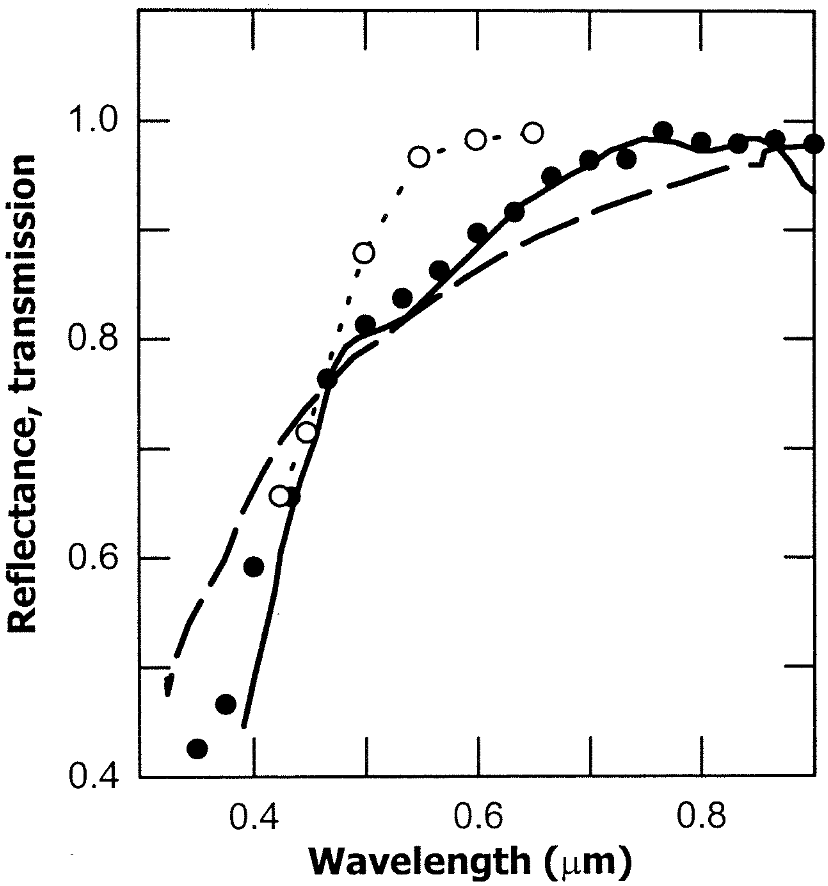
The origin of Europa's sulfurous material may have been ion implantation from jovian plasma bombardment [3], with the surface distribution subsequently modified by geological processes. Endogenic sources may also have provided sulfur or sulfate [4]. If ion implantation is the major source, then a resurfacing rate of 0.02 microns/year is suggested, which is about a factor of five less than that estimated by Squyres et al. [5].

The surfaces of Ganymede and Callisto are thought to contain sulfur dioxide [6] and hydrogen peroxide [7] so their surfaces are also likely to contain sulfuric acid . Regions of Ganymede's surface exhibit spectra with asymmetric hydration bands, consistent with the presence of sulfuric acid hydrate.

[1] Carlson, R. W., R. E. Johnson, M. S. Anderson, *Science*, in press (1999). [2] Noll, K. S., H. A. Weaver, A. M. Gonella, *J. Geophys. Res.* **100**, 19057 (1995). [3] Lane, A. L., R. M. Nelson, D. L. Matson, *Nature* **292**, 38 (1981). [4] Hogenboom, D. L., et al., *Icarus* **115**, 258 (1995); McCord, T. B., et al., *Science* **280**, 1242 (1998). [5] Squyres, S. W., et al., *Nature* **301**, 225 (1983). [6] Domingue, D. L., A. L. Lane, R. A. Beyer, *Geophys. Res. Lett.* **25**, 3117 (1998); Noll, K. S. et al., *Geophys. Res. Lett.* **24**, 1139 (1997). [7] Hendrix, A. R., et al., *Lunar Planet. Sci. XXX.*



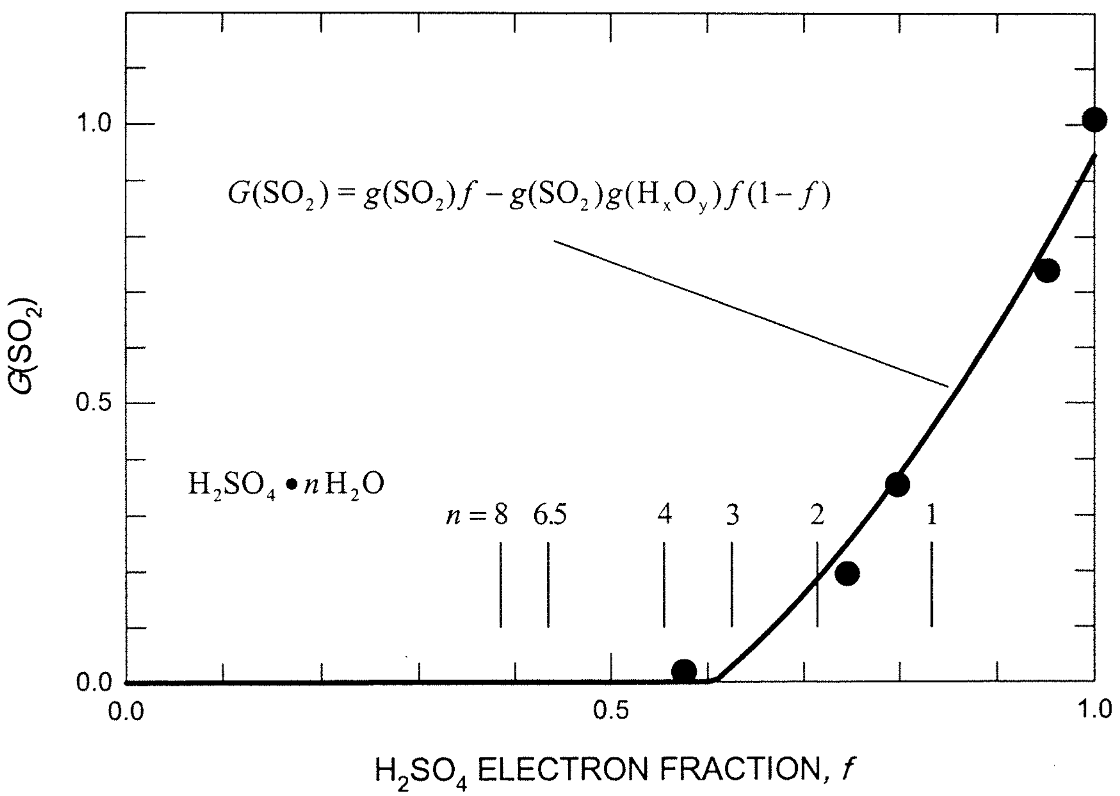
A
B
C
D
Natron
Mg Hexahydrate
Epsomite
Reflectance
Wavelength (μm)
0.0
0.2
0.4
0.6
0.8
1.0
1.5
2.0
2.5



1.0
0.8
0.6
0.4
Reflectance, transmission
0.4
0.6
0.8
Wavelength (μm)

Sulfate Destruction, $G(SO_2)$

Data from Hochanadel, Ghormley, and Sworski,
J.A.C.S. **77**, 3215 (1955)
Theoretical fit includes recombination processes



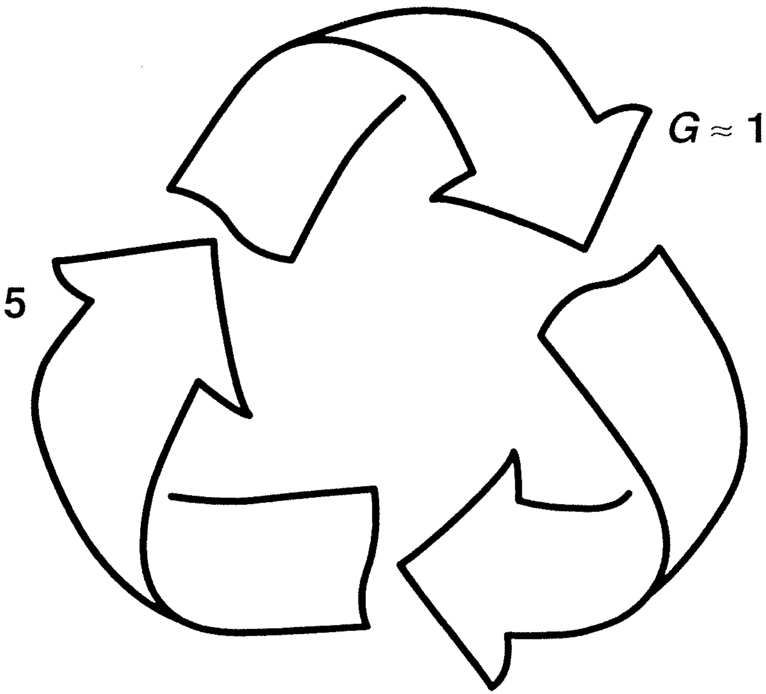
THE RADIOLYTIC SULFUR CYCLE

$H_2SO4 \cdot n\, H_2O$

$(n = 6.5, 8)$

$G \approx 10^{-3}$

$G \approx 0.6 - 5$



SO_2, S_x, S_xO (?)